Modeling and Evaluation of Bi-Static Tracking In Very Shallow Water

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LONG TERM GOALS

Improve passive acoustic tracking capabilities in shallow water by extending the concepts developed to date for the ANS sonar system, and developing an acoustic model for AUV mission planning and data assessment.

OBJECTIVES

1) Build and test a two man deployable autonomous passive sonar (SQUID) to add a bi-static capability to the Ambient Noise Sonar (ANS).
2) Develop acoustic models for tracking error estimation, reduction and evaluation.
3) Experimentally calibrate and evaluate the acoustic model and the sonar in very shallow water as it pertains to a typical AUV operation.
4) Experimentally evaluate bi-static tracking and modem signature distortion in varying surface wave conditions and directions.
5) Develop, and evaluate at sea, an environmentally based numerical model which predicts frequency selective fading and surface Doppler effects on acoustic tracking and performance.

APPROACH

To achieve the multiple objectives of this project the approach has been broken down into three principle tasks (1) design and build of a two man deployable array (2) development of numerical models, and (3) experimental testing and evaluation of systems and models in the SFTF range.

WORK COMPLETED

1) Autonomous passive sonar: The SQUID is a two man deployable Ambient Noise Sonar (ANS) that is anchored to the ocean bottom allowing mid-water data acquisition. The system consists of 5 hydrophones, one that is attached to a centrally fixed arm and four that are mounted to hinged arms which unfold to a cruciform arrangement (Figure 1). A hydraulic ram opens the four hinged arms when activated by a hydraulic motor as shown in Figure 2. The hydrophones are ITC 6050-C low noise hydrophones, which are sampled by an Innovative Integration ADC64, 8 channel, 16-bit data acquisition board sampling at 100 kHz. A Precision Navigation TCM2 compass measures heading, pitch and roll and a pressure transducer provides depth. The data is stored to a 12 Gbyte hard drive with a PCM 9570/S motherboard using a 500 MHz Celeron processor. Hydrophone data is taken for

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14. ABSTRACT
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15. SUBJECT TERMS

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1.1 seconds every five seconds and written to disk. The length of time that data is taken and the sampling rate can be modified with the data logging software to fit the needs of the mission. The data logging and motor controlling software can be compiled so that the arms open and data logging begins a specified amount of time after the system is turned on. The system logs a predetermined number of files and then closes the arms. This allows versatile missions and autonomous deployment from a small research vessel without the need for divers. Sea trials for this system have been completed and data analysis algorithms are now being optimized.

Figure 1: The SQUID passive sonar with arms folded and buoyancy foam.

Figure 2:The SQUID passive sonar with arms open.

2) Development of acoustic tracking models: Navigation software is a critical part of an Autonomous Underwater Vehicle (AUV) system. Due to its complex nature, testing and debugging of navigation software often involve long and costly sea trials. Modeling and simulation is a cost-effective way to minimize unnecessary operational overhead. Navigation systems can be tested with different simulated sensor signals so that even very well hidden bugs can be possibly simulated and debugged. This aspect of the project developed an acoustic model to be used in a simulator of AUV navigation using a long baseline acoustic sonar system. The goals of this work are twofold: to develop a mechanism with which to test vehicle position software against a benchmark analytical solution, and to assess the LBL navigation performance as a function of operational conditions.

Two Acoustic Models were used to simulate underwater acoustic signal propagation, a Gaussian Beam Ray tracing model and the Method of Images. The former can be applied to a variety of 3- dimensional environments and the latter is used to benchmark the system since it gives exact results. The acoustic models developed in this project were combined with the simulation work carried out under project number N00014-96-1-5029 In which the AUV simulator was developed.

3) Experiments were successfully conducted in the SFTF range on in March, May and September 2001 to evaluate the shallow water tracking of the Peacock and Squid arrays. The arrays were deployed from the R.V. Stephan to track a Trackpoint source mounted 2.44 m. below the R.V. Oceaneer. The R.V. Oceaneer took outgoing and incoming headings from the arrays up to ranges of over 2 km.

Experimental evaluation of bi-static tracking was completed in September 2001 using both the Peacock and SQUID arrays. The Peacock was deployed at the same location as the May experiment in 32 feet of water. The SQUID was deployed approximately 500 meters south east of the Peacock location at a depth of 35 feet in 54 feet of water.

Experiments are planned to take place in October 2001 to investigate modem signature distortion in varying surface wave conditions and directions. This experiment is necessary to complete objective 5, an environmentally based numerical model to predict frequency selective fading and surface Doppler effects on acoustic tracking and performance.

RESULTS

1) Development of the mechanics of the SQUID sonar have been completed and tested at sea. The system was first put to sea in March 2001 without the hydraulic system and again in September 2001 with all systems active. It has been shown that the system can be deployed in an autonomous mode. All that is required to deploy the system is to compile the program to fit the time duration of the mission requirements before going to sea and then turning on the system at sea. The SQUID will then open the hydrophone arms, log data for the predetermined amount of time, and then close its arms for easy retrieval.

2) Development of numerical acoustic tracking models: Models have been developed for simulation of AUV navigation performance from acoustic beacons. The simulation results generated from different trigger levels on the LBL system are shown in Figure 3, Figure 4, and Figure 5 respectively. The solid line is the vehicle true path during the mission whereas the black dots are the estimated vehicle position using the vehicle position estimator software. The circles in each plot indicate the four beacon positions.

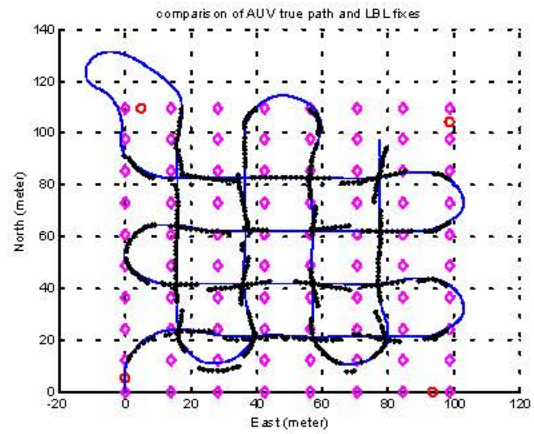

Figure 3: Comparison with 0.005 trigger level

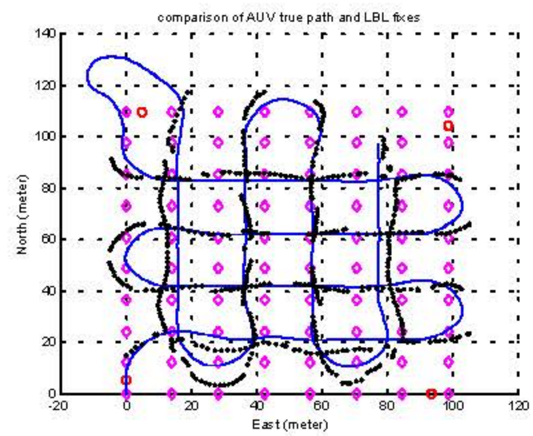

Figure 4: Comparison with 0.01 trigger level

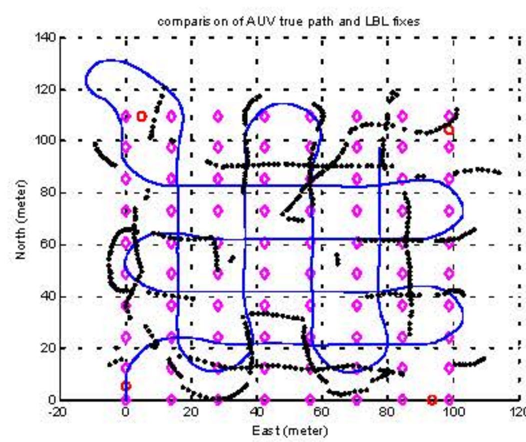

Figure 5: Comparison with 0.013 trigger level

These results show that as the trigger level is increased the accurcy of the navigation is reduced significantly. However, even with a very small trigger level (Figure 3), the vehicle embedded LBL software could not always compute a fix. There are several reasons for that, including the errors in the reply-time table, and the errors introduced by interpolation. Significant errors (peaks) always appear in the area close to the transmitted beacon. However, most of them are quite small, and can not explain the LBL failures in the center part of the rectangle. These results led us to believe that there are algorithmic bugs in the embedded LBL position estimation software.

3) The experiment conducted in May was used to calibrate and evaluate tracking capabilities in shallow water. Data was also taken during the May experiment with the target beacon stationary to calibrate the tracking abilities of the Peacock ANS. Very good tracking abilities were demonstrated close to the array, but at ranges greater than 2km the lower signal to noise reduced tracking capability.

4) Experimental evaluation of bi-static tracking was carried out in September 2001. Preliminary results demonstrate successful tracking, but some algorithm development on the Squid system is still needed to improve bearing calculations.

IMPACT

An autonomous Ambient Noise Sonar, Squid, has been developed and tested to provide both quick and cost effective deployment from a small surface vessel. This new system also allows bi-static tracking capabilities when used in conjunction with the existing Peacock array. It has also been demonstrated that both systems can obtain target bearing angles and will provide bi-static tracking with further development.

AUV navigation modeling and results have been presented. The simulation is a cost-effective way to assess acoustic navigation performance of the embedded software, and the simulation results revealed unexpected holes in the LBL fixes, which could have been caused by hidden bugs in the position code.

PUBLICATIONS

Feijun Song, Anthony LaVigne, Edgar An, Stewart Glegg "An Assessment Of AUV Navigation Performance Using Long Baseline Acoustic Modeling And Simulation", 12th UUST Symposium Durham, New Hampshire, August 2001